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Scope of Research

The conventional electronics utilizes only the “electric charge” of electrons. On the other hand, the conventional magnetic devices utilize only the “spin” of electrons. A new field of electronics called *spintronics*, in which both “charge” and “spin” of electrons are utilized in solid-state devices, has been rapidly developing. We are searching for new functional materials which lead to developments of novel spintronic devices by using fabrication techniques such as film growth in units of atom and electron-beam lithography with a resolution of several tenth nano-meters.

Research Activities (Year 2004)

Presentations

Current-driven domain wall motion in magnetic nano-wires, Ono T, IFCAM workshop on Nanoscience/Nanotechnology, 3 - 5 March 2004, Sendai, Japan.

Dynamics of a magnetic domain wall in magnetic wires, Ono T, International Conference on Nanospintronics Design and Realization, 24 - 28 May 2004, Kyoto, Japan.

Spin-dependent transport in ferromagnet/superconductor/ferromagnet double tunnel junctions, Miura K, Ono T, Nasu S, International Conference on Nanospintronics Design and Realization, 24 - 28 May 2004, Kyoto, Japan.

Dynamics of a magnetic domain wall in submicron magnetic wires with asymmetric notches, Himeno A, Okuno T, Ono T, International Conference on Nanospintronics Design and Realization, 24 - 28 May 2004, Kyoto, Japan.

Current-driven domain wall motion in magnetic nano-wires, Ono T, 5th International Symposium on Metallic Multilayers, 7 - 11 June 2004, NIST, Boulder, USA.

Electrical spin injection in $\text{Ni}_{81}\text{Fe}_{19}/\text{Al}/\text{Ni}_{81}\text{Fe}_{19}$ double tunnel junctions, Miura K, Ono T, Nasu S, 5th International Symposium on Metallic Multilayers, 7 - 11 June 2004,

NIST, Boulder, USA.

Propagation of a Magnetic Domain Wall in Submicron Magnetic Wires with Asymmetric Notches, Himeno A, Okuno T, Ono T, 5th International Symposium on Metallic Multilayers, 7 - 11 June 2004, NIST, Boulder, USA.

Spin Structure of Cr in Cr/Sn Multilayers with bcc(110) orientation, Jiko N, Mibu K, Takeda M, 5th International Symposium on Metallic Multilayers, 7-11 June 2004, NIST, Boulder, USA.

MFM study on current-driven domain wall motion in ferromagnetic nano-wires, Ono T, 7th Oxford-Kobe Materials Seminar, 2 - 4 September 2004, Kobe Institute, Kobe, Japan.

Direct observation of current-driven domain wall motion in magnetic nano-wires, Ono T, International Workshop on Materials Science and Nano-Engineering, 11 - 14 December 2004, Osaka, Japan.

Grants

Ono T, Dynamics of a single domain wall in artificially structured magnetic wires, Grant-in-Aid for Scientific Re-

Current-driven Domain Wall Motion in Magnetic Nanowires

Manipulation of a magnetic state by a spin-polarized current is one of the exciting topics in solid state physics. We succeeded in driving a magnetic domain wall (DW) in magnetic nanowires by flowing an electric current through the wire. Figure 1 shows the real-space observation of this current-driven DW motion by using the magnetic force microscopy (MFM). These are successive MFM images with one pulsed-current applied between each consecutive image. The current density and the pulse duration were $6.7 \times 10^{11} \text{ A/m}^2$ and $0.5 \text{ } \mu\text{s}$, respectively, and the current direction was from left to right. Here, a DW in the wire is imaged as a dark contrast. The directions of the magnetization in the wire were indicated by the blue and red arrows. This result shows that an electric current can drive the DW and change the magnetic configuration without a magnetic field. We can control the DW position in the wire by tuning the intensity, the duration and the polarity of the pulsed-current.

Yamaguchi A., Ono T., *et al.*, Phys. Rev. Lett., **92** (2004) 077205.

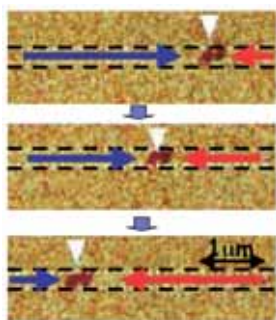


Figure 1. Real-space observation of the current-driven domain wall motion by a magnetic force microscopy.

Spin-injection into Non-magnetic Metal

Creation, transport and detection of spins are building blocks of spintronics. The efficient spin injection, accumulation, and transport are central issues to be explored

in manipulating the spin degree of freedom of electron. We performed spin injection experiments for $\text{Ni}_{81}\text{Fe}_{19}/\text{Al}/\text{Ni}_{81}\text{Fe}_{19}$ with double tunnel junctions. Figure 2 shows a scanning electron microscope image of the sample and the geometry of the non-local transport measurements. The sample was fabricated on thermally oxidized Si substrates by electron-beam lithography for patterning, oblique deposition, and lift-off method. The sample has two $\text{Al}/\text{Al}_2\text{O}_3/\text{Ni}_{81}\text{Fe}_{19}$ tunnel junctions at the overlap of the Al wire and the $\text{Ni}_{81}\text{Fe}_{19}$ wires. A current I enters from the left $\text{Ni}_{81}\text{Fe}_{19}$ electrode and is extracted at the left end of the Al wire. Spin polarized electrons injected from $\text{Ni}_{81}\text{Fe}_{19}$ into Al create nonequilibrium spin accumulation in Al. This spin accumulation is detected as voltage V measured between the right $\text{Ni}_{81}\text{Fe}_{19}$ electrode and the right end of the Al wire. Figure 3 shows the spin-signal V/I at 10 K as a function of a magnetic field. The measurements were performed by DC four terminal method using a current of $I = 5 \text{ } \mu\text{A}$. The configuration of magnetizations of $\text{Ni}_{81}\text{Fe}_{19}$ electrodes are schematically indicated by arrows in the figure. The sign of the spin-signal V/I reverses when the relative magnetization configuration between two $\text{Ni}_{81}\text{Fe}_{19}$ electrodes changes from parallel to anti-parallel, indicating the existence of the difference in electrochemical potentials between the spin-up and spin-down electrons injected from $\text{Ni}_{81}\text{Fe}_{19}$ into the Al wire.

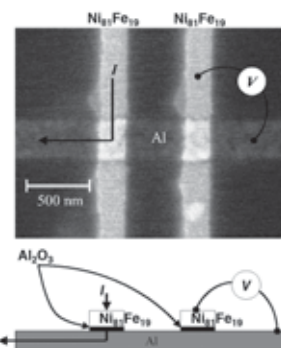


Figure 2. SEM image of the spin injection and detection device, with the geometry of the non-local measurement.

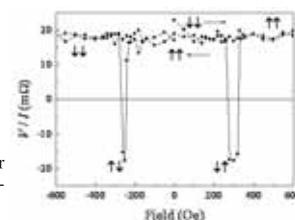


Figure 3. Spin-signal V/I for $\text{Ni}_{81}\text{Fe}_{19}/\text{Al}/\text{Ni}_{81}\text{Fe}_{19}$ as a function of magnetic field at 10 K.

search (C) (2), 1 April 2003 - 31 March 2005.

Ono T, Nanospintronics Design and Realization, MEXT Special Coordination Funds for Promoting Science and Technology, 1 September 2002 - 31 March 2005.

Ono T, Invention of anomalous quantum materials, Grant-in-Aid for Scientific Research in Priority Areas, 1 April 2004 - 31 March 2010.

Award

Yamaguchi A, Tanigawa H, Ono T, Nasu S, Miyake K, Mibu K, Shinjo T, MSJ Distinguished Paper Award, Current-driven domain wall motion due to the spin-transfer effect, Magnetism Society of Japan, 22 September 2004.